In-Situ Characterization Tools for ECR Plasma Etching

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The dry etching of compound semiconductors is one of the critical processing steps in fabricating integrated photonic devices. Dry etching capabilities are important for transferring patterns from defined masking materials to the semiconductor on a micron and nanometer scale. The resulting structure needs to have a smooth etched morphology and a predictable anisotropic profile. To deliver high-precision etching that our devices require we need to move from a mostly empirical understanding of the thermodynamic and chemical properties to an analytical understanding. In this project we have set out to enhance our capabilities to characterize our plasma etching technology by *in-situ* temperature thermometry and end point detection. These types of analytical characterization tools are needed to provide reproducible, precision depth control as well as insight into the chemical etching mechanisms.

Project Goals

The goal of this project was to select and install an *in-situ* wafer surface temperature measurement diagnostic and a plasma chemistry diagnostic on an existing ECR etch tool.

Relevance to LLNL Mission

We support projects that require advanced InP- and GaAs-based processing technology. There are many different devices having broad applications that share the same fabrication hurdles. Figure 1 shows representative sample devices, all requiring similar process technology. This technology will allow deployable microfabricated systems for several applications that are at the core of LLNL's national security mission, such as high-speed radiation diagnostic devices for NIF, single-transient recording technologies, and devices for encryption applications.

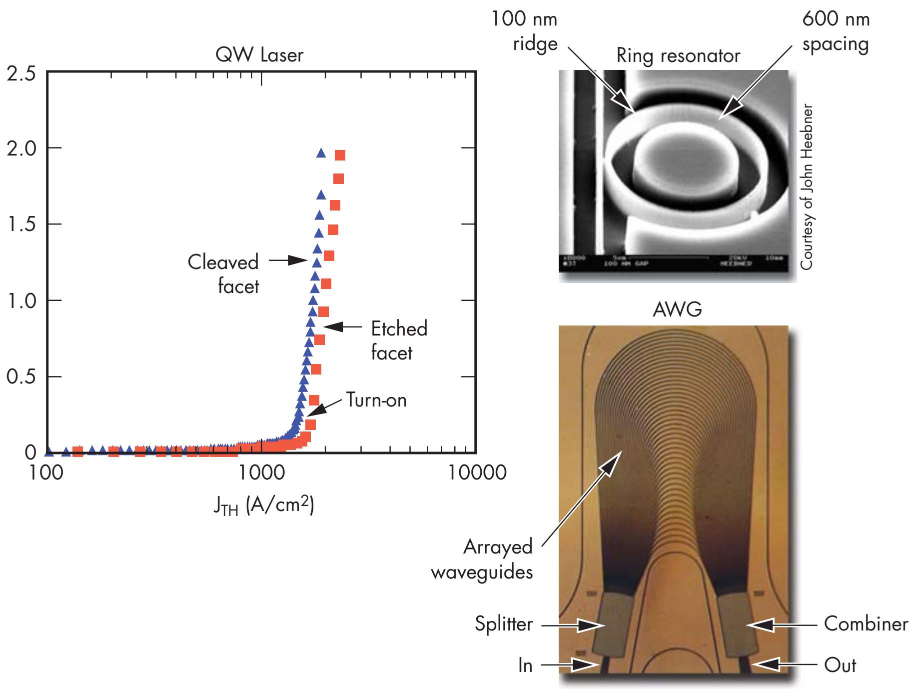

Figure 1. Sample devices we have fabricated, all requiring advanced plasma dry etching, carried out with our ECR system.

FY2004 Accomplishments and Results

Selecting appropriate temperature and plasma chemistry diagnostic tools was limited by the harsh environment of the etch chamber. Corrosive chemical gases, along with RF and microwave radiation and strong DC magnetic fields, render electronic technologies useless.

We therefore chose a contacting temperature probe that relies on a well-characterized temperature dependence of a phosphor decay that can be interrogated through an optical fiber and is encased in chemical resistant materials. Figure 2 shows temperature vs. time collected for typical GaAs etch recipes. The ECR plasma has a dramatic impact on the surface temperature of the wafer. Although we had indirect indications of the peak wafer temperatures in the past, this was our first measurement of the actual time evolution of the temperatures. This information will make further optimization possible.

To characterize the chemical composition of the plasma, and thus indirectly measure the chemical composition of the wafer surface currently being etched, we selected a plasma emission spectrometry tool. This tool collects the light emitted by the plasma through a viewport on the etch chamber and separates the light into its various spectral components. By analyzing the variations of the emission spectrum as a function of time in real time (Fig. 3), the boundary between different layers on the sample can be identified and used to control the etch process. The installation and calibration of the analytical tools is complete. The final requirement is to create endpoint detection recipes based on the identification of the measured spectrum for the various devices that are being fabricated.

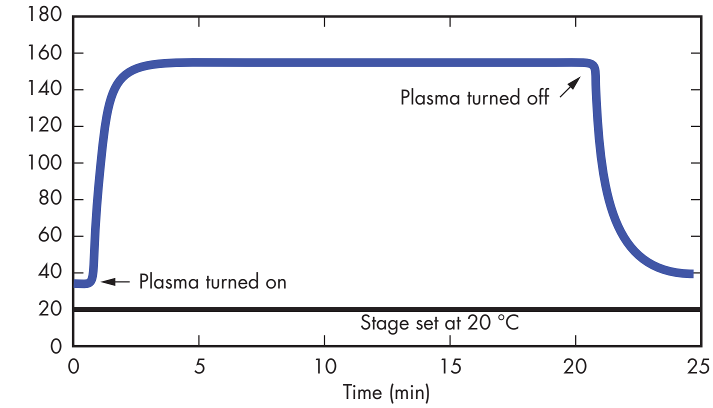

Figure 2. Temperature of surface of GaAs wafer during ECR etch process with He backside cooling, as recorded by optical contact thermometry.

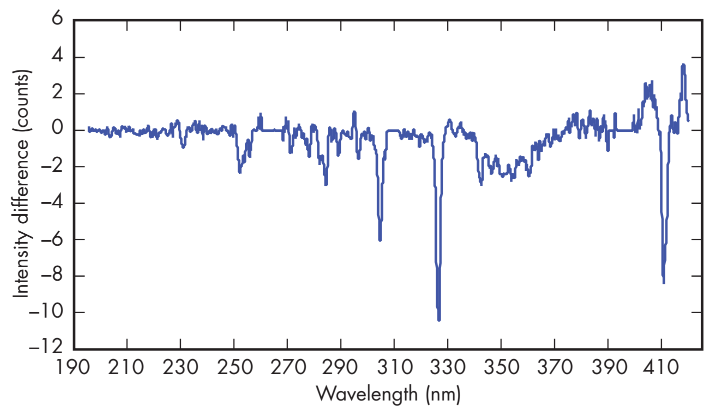

Figure 3. Calculated difference between spectrum recorded during InP etch and another spectrum recorded during InGaAsP etch. Key wavelengths of interest are clearly visible as sharp peaks.

Related References

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